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EFFECTS OF WING PLANFORM ON THE AERODYNAMIC CHARACTERISTICS OF A WING-BODY-TAIL MODEL AT MACH NUMBERS 3.96 AND 4.63

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SUMMARY

An investigation has been conducted in the Langley Unitary Plan wind tunnel to determine the effects of several wing leading- and trailing-edge modifications on the aerodynamic characteristics of a wing-body-tail model at Mach numbers of 3.96 and 4.63. Tests were made with and without a vertical tail. The tests were conducted at angles of attack from about -2° to 19° for angles of sideslip of about 0° and 5°. The Reynolds number per foot was 3×10^{6} (per meter, 9.84×10^{6}). The data are presented without analysis.

INTRODUCTION

Currently there is an extensive research effort being devoted to determining the aerodynamic characteristics of aircraft configurations capable of supersonic flight to Mach numbers above 4. As a part of this research effort, investigations are being made to determine the effects of variations in wing planform on the stability and performance characteristics of various research models. A large amount of data is available in the lower supersonic speed region (refs. 1 to 4); however, with the exception of the results contained in reference 5, data above a Mach number of 3 are very meager.

The purpose of the present investigation was to extend the Mach number range of some of the configurations given in reference 1. The basic model consisted of an ogive-cylinder body and a 61.70° swept wing. The various wing-planform modifications included a full-span leading-edge extension with a sweep angle of 67.01°, a semispan leading-edge extension with a sweep angle of 70.71°, and a full-span trailing-edge extension which filled in the trailing-edge notch to produce a clipped-delta planform. The various wing-planform configurations were tested with and without a vertical tail. The tests were conducted at Mach numbers of 3.96 and 4.63 through an angle-of-attack range from about -2° to 19° for angles of sideslip of about 0° and 5°. The Reynolds number per foot was 3×10^{6} (per meter, 9.84×10^{6}). The data are presented without analysis.

SYMBOLS

The results are presented in coefficient form with lift, drag, and pitching-moment coefficients referred to the stability-axis system and rolling-moment, yawing-moment, and side-force coefficients referred to the body-axis system.

Measurements for this investigation were taken in U.S. Customary Units. Equivalent values are indicated parenthetically in the International System of Units (SI). Factors relating the two systems are given in reference 6.

b	wing span, 20.000 in. (0.508 m)
$\bar{c}$	mean geometric chord, in. (m)
$\bar{c}_b$	mean geometric chord of basic wing, 5.417 in. (0.138 m)
C_D	drag coefficient, $\frac{\text{Drag}}{qS}$
$C_{D,b}$	drag coefficient based on area of basic wing, $\frac{\text{Drag}}{qS_b}$
C_L	lift coefficient, $\frac{\text{Lift}}{qS}$
$C_{L,b}$	lift coefficient based on area of basic wing, $\frac{\text{Lift}}{qS_b}$
C_l	rolling-moment coefficient, $\frac{\text{Rolling moment}}{qSb}$
$C_{l,b}$	rolling-moment coefficient based on area of basic wing, $\frac{\text{Rolling moment}}{qS_b b}$
$C_{l_\beta} = \frac{\Delta C_l}{\Delta \beta}$	
$C_{l_{\beta,b}} = \frac{\Delta C_{l,b}}{\Delta \beta}$	
C_m	pitching-moment coefficient, $\frac{\text{Pitching moment}}{qS\bar{c}_b}$
$C_{m,b}$	pitching-moment coefficient based on area of basic wing, $\frac{\text{Pitching moment}}{qS_b\bar{c}_b}$
$\left(C_{m,b}\right)'$	pitching-moment coefficient based on area of basic wing and computed about a moment center yielding a static margin of $0.185\bar{c}_b$, $\frac{\text{Pitching moment}}{qS_b\bar{c}_b}$

C_n yawing-moment coefficient, $\frac{\text{Yawing moment}}{qSb}$

$C_{n,b}$ yawing-moment coefficient based on area of basic wing, $\frac{\text{Yawing moment}}{qS_b b}$

$C_{n_\beta} = \frac{\Delta C_n}{\Delta \beta}$

$C_{n_{\beta,b}} = \frac{\Delta C_{n,b}}{\Delta \beta}$

C_Y side-force coefficient, $\frac{\text{Side force}}{qS}$

$C_{Y,b}$ side-force coefficient based on area of basic wing, $\frac{\text{Side force}}{qS_b}$

$C_{Y_\beta} = \frac{\Delta C_Y}{\Delta \beta}$

$C_{Y_{\beta,b}} = \frac{\Delta C_{Y,b}}{\Delta \beta}$

L/D lift-drag ratio

M free-stream Mach number

q free-stream dynamic pressure, lb/ft^2 (N/m^2)

S respective wing area, ft^2 (m^2)

S_b basic wing area, 0.694 ft^2 (0.064 m^2)

α angle of attack referred to fuselage center line, deg

β angle of sideslip referred to fuselage center line, deg

Designations of model components:

B body

W wing

T vertical tail

APPARATUS AND TESTS

Model

A drawing of the model is presented in figure 1 and a photograph of the model is shown in figure 2. The model had a cylindrical body with an ogive nose, a wing spar, three wing leading edges (one basic and two modifications), one trailing-edge modification, and a vertical tail. The body had a fineness ratio of 12.5. The basic-wing leading edge had a sweep angle of 61.70°. The other two leading edges provided a forward extension of 67 percent of the basic-wing root chord at the fuselage center line. From the fuselage center line, one of the leading-edge extensions tapered linearly to zero at 50 percent $b/2$ and the other to zero at 100 percent $b/2$; the leading-edge sweep of these extensions was 70.71° and 67.01°, respectively. The trailing-edge insert provided a rearward extension of 181 percent of the basic-wing root chord at the fuselage center line and tapered linearly to zero at the wing tip. The basic wing had an airfoil section consisting of the forward one-third of an NACA 63-006 airfoil which faired into the spar and had a constant thickness from the 33.3-percent-chord line to the trailing edge. The same airfoil shape was used for the two leading-edge modifications with a slab section inserted between the spar and the leading edge. The trailing-edge modification had a slab section with a spanwise thickness distribution identical to that of the spar. The vertical tail was a constant-thickness slab which had a wedge-shape leading edge and a taper ratio of about 0.514.

Wing Identification

A two-group numbering system is used to identify the various wing planform configurations. For example, the first group of the identification 67_{50}-181_{100} refers to the leading-edge extension and gives the amount of extension of the basic-wing root chord in percent. The associated subscript gives the spanwise extent of the leading-edge modification in percent semispan. The second group, including its subscript, refers to the trailing-edge modification and represents the basic-wing root-chord extension in percent and the spanwise extent of the modification in percent semispan. Thus, for the configuration 67_{50}-181_{100}, the wing leading edge (L.E.) has been extended forward at the root 67 percent of the basic-wing root chord with the extension tapering to zero at 50 percent $b/2$ and the trailing edge (T.E.) has been extended rearward at the root 181 percent of the basic-wing root chord with the extension tapering to zero at 100 percent $b/2$. The basic-wing leading or trailing edge is referred to by the identification 0_0.

Tunnel

Tests were conducted in the high Mach number test section of the Langley Unitary Plan wind tunnel, which is a variable-pressure, continuous-flow tunnel. The test section is about 4 feet (121.92 cm) square and 7 feet (213.36 cm) long. The nozzle leading to the test section is of the asymmetric sliding-block type which permits a continuous variation in test-section Mach number from about 2.3 to 4.7.

Test Conditions

The stagnation temperature and pressure for the Mach numbers of this investigation are as follows:

Mach number	Stagnation temperature		Stagnation pressure	
	^{o}F	^{o}K	lb/ft^{2}abs	N/m^2
3.96	175	353	5775	276 500
4.63	175	353	7883	376 500

The Reynolds number per foot for both Mach numbers was 3.0×10^6 (per meter, 9.84×10^6). The dewpoint measured at stagnation pressure was maintained below -30^{o} F (240^{o} K) for all tests in order to assure negligible condensation effects. Tests were conducted through an angle-of-attack range from about -2^{o} to 19^{o} at angles of sideslip of about 0^{o} and 5^{o}. Boundary-layer transition strips 1/16 inch (0.159 cm) wide and consisting of No. 60 carborundum grains were affixed around the fuselage 0.7 inch (1.778 cm) from the nose and 0.7 inch (1.778 cm) from the leading edge of the wing and tail surfaces in a streamwise direction.

Measurements

Aerodynamic forces and moments were measured by means of a six-component electrical strain-gage balance housed within the model. The balance, in turn, was mounted to a sting support system. The balance chamber pressure was measured for each model by means of a single static orifice located in the balance cavity.

Corrections and Accuracy

Angles of attack and sideslip were corrected for deflection of the balance and sting under aerodynamic load. Angles of attack were also corrected for tunnel flow misalinement. Drag data were adjusted to correspond to free-stream static conditions in the balance chamber.

Based on calibrations and repeatability of the data, the various measured quantities are estimated to be accurate within the following limits:

C_D	±0.001
C_L	±0.01
C_l	±0.0005
C_m	±0.005
C_n	±0.001
C_Y	±0.007
α, deg	±0.10
β, deg	±0.10
M	±0.05

PRESENTATION OF RESULTS

The results of the present investigation, which was undertaken to extend the Mach number range of reference 1, are presented without analysis. An outline of the contents of the data figures is as follows:

	Figure
Aerodynamic characteristics in pitch for body alone	3
Aerodynamic characteristics in pitch for various test configurations with tail off:	
Based on respective wing areas and model moment center	4
Based on area of basic wing and a constant low-lift static margin	5
Variation of sideslip parameters with angle of attack for various test configurations (based on respective wing areas and model moment center)	6
Effect of leading-edge extension on variation of sideslip parameters with lift coefficient (based on area of basic wing and model moment center)	7
Effect of trailing-edge extension on variation of sideslip parameters with lift coefficient (based on area of basic wing and model moment center)	8

CONCLUDING REMARKS

Tests have been conducted at Mach 3.96 and 4.63 to determine the effects of wing planform on the aerodynamic characteristics of a wing-body-tail model. The basic model consisted of an ogive-cylinder body and a 61.70° swept wing. The various wing planform modifications included a full-span leading-edge extension with a sweep angle of 67.01°, a semispan leading-edge extension with a sweep angle of 70.71°, and a full-span trailing-edge extension which filled in the trailing-edge notch to produce a clipped-delta planform. Tests were made with and without a vertical tail. The tests were conducted at angles of attack from about -2° to 19° for angles of sideslip of about 0° and 5°. The Reynolds number per foot was 3×10^6 (per meter, 9.84×10^6). The data are presented without analysis.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., March 8, 1966.

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1. McKinney, Royce L.; and Jernell, Lloyd S.: Effects of Wing Planform on the Aerodynamic Characteristics of a Wing-Body-Tail Model at Mach Numbers 1.57, 2.16, and 2.87. NASA TM X-1065, 1965.

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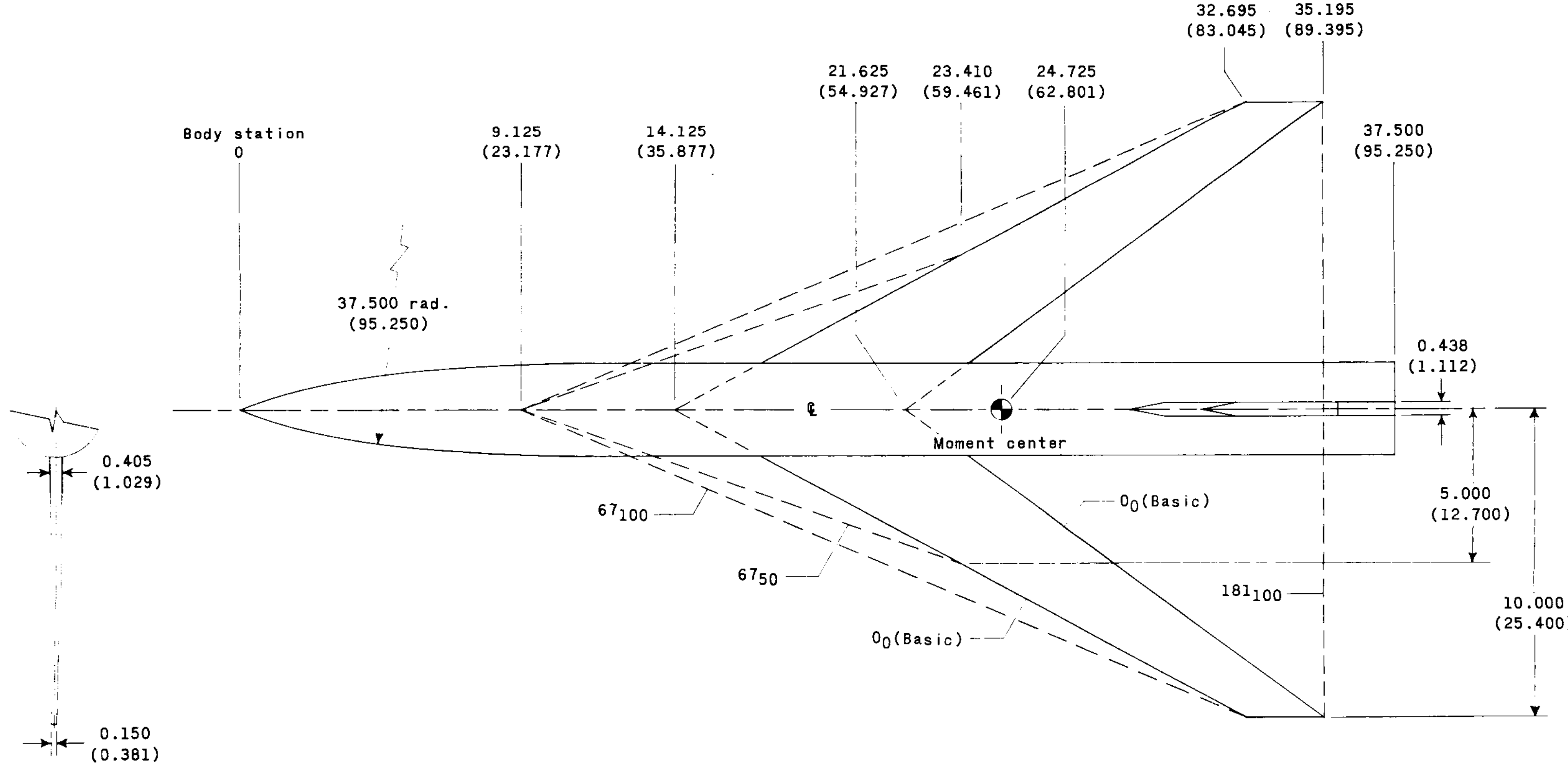

Partial front view

Wing		S		$\bar{c}$		0.25 $\bar{c}$ body station	
L.E.	T.E.	sq ft	sq m	in.	cm	in.	cm
0_0	0_0	0.694	0.064	5.417	13.759	23.217	58.971
67_{50}	0_0	0.868	0.081	7.667	19.474	20.851	52.961
67_{100}	0_0	1.042	0.097	8.611	21.872	20.444	51.928
0_0	181_{100}	1.637	0.152	14.224	36.129	24.528	62.301
67_{100}	181_{100}	1.984	0.184	17.526	44.516	22.048	56.002

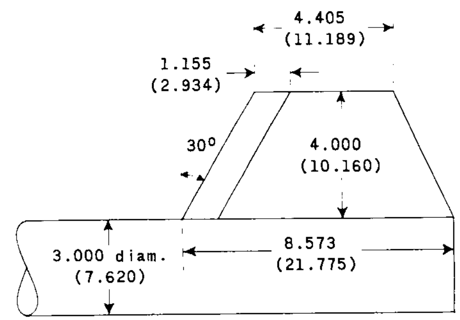

Figure 1.- Model details. (All dimensions given first in inches and parenthetically in centimeters unless otherwise noted.)

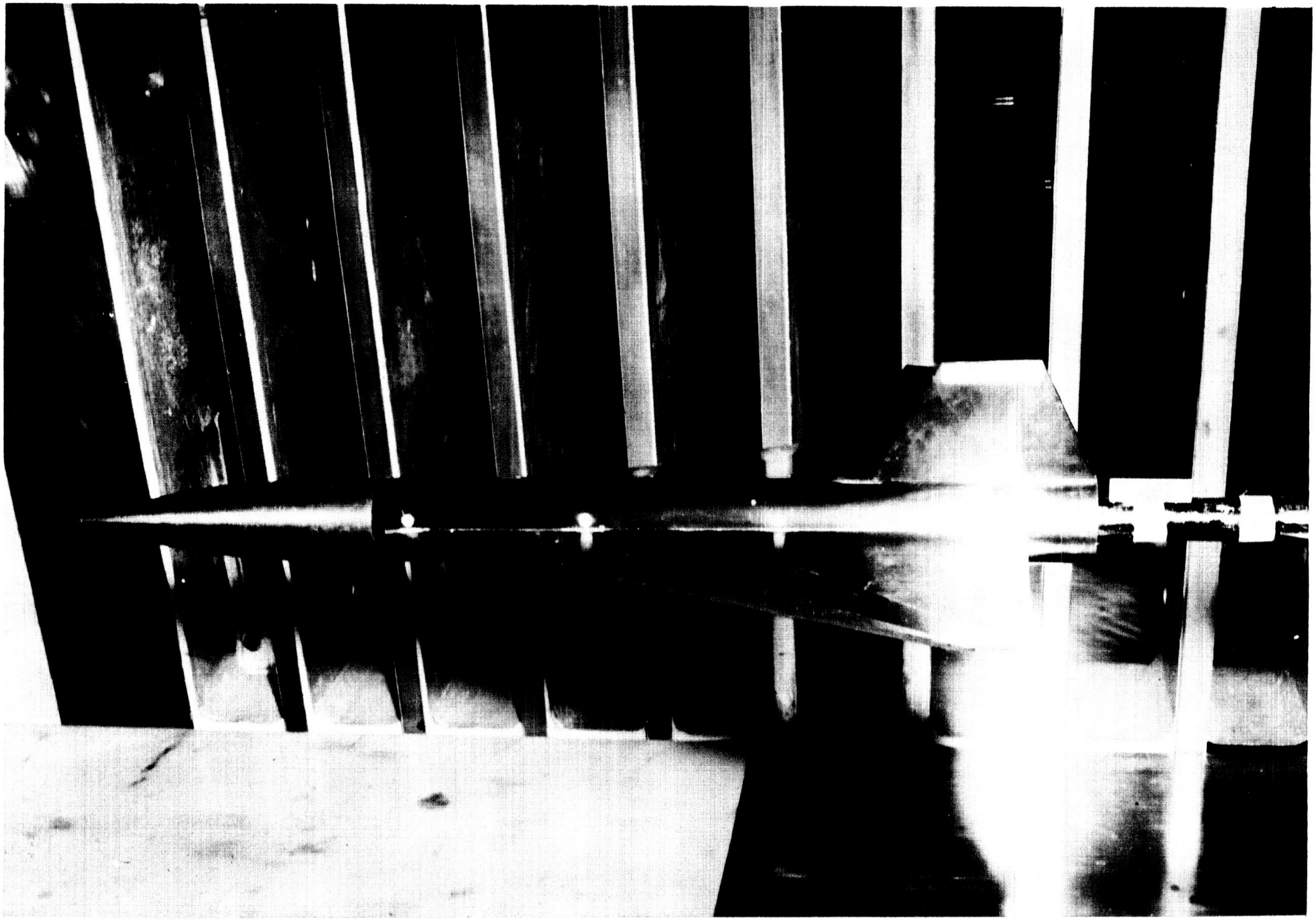

Figure 2.- Configuration 67_{100}-181_{100} mounted in test section.

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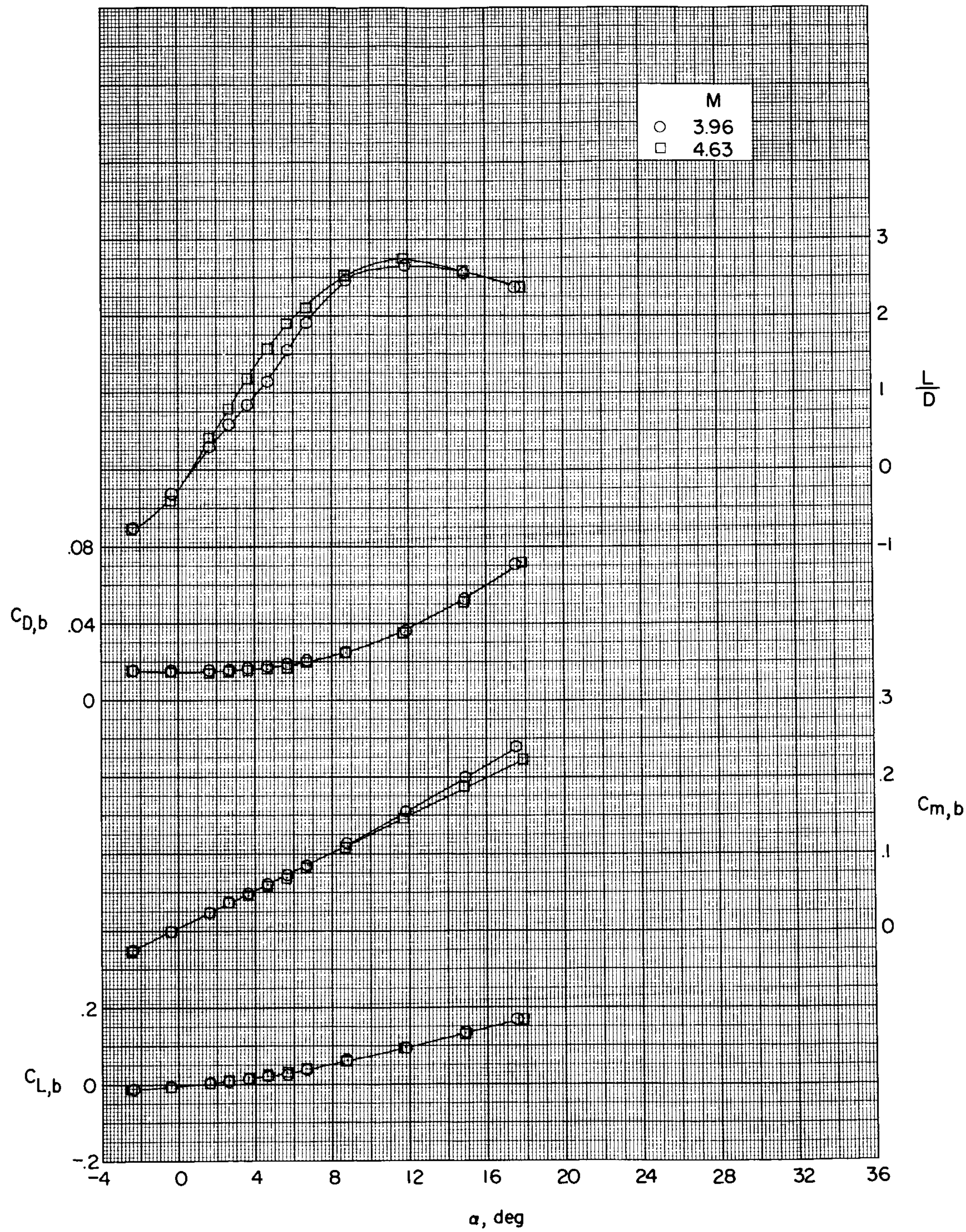
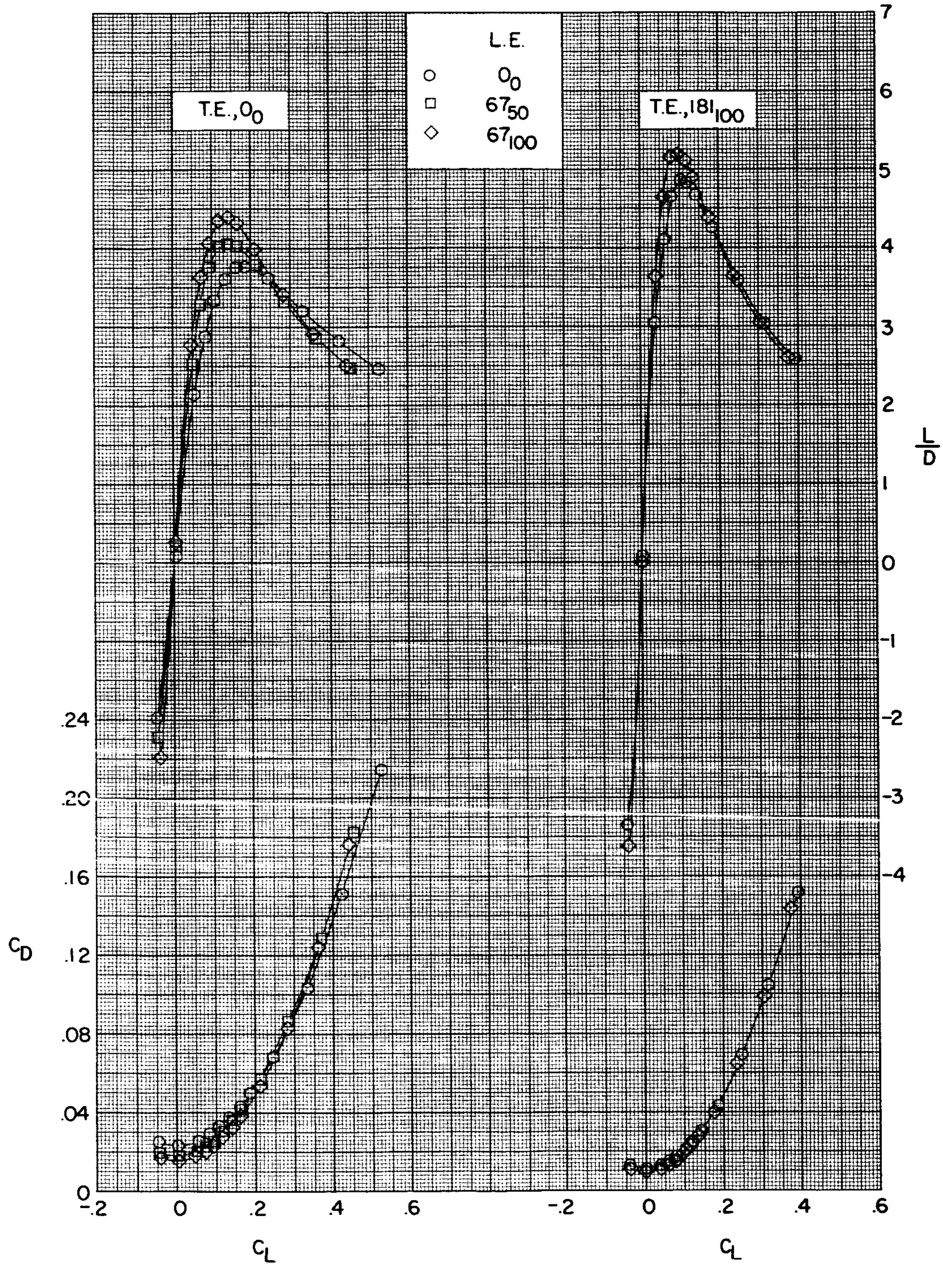
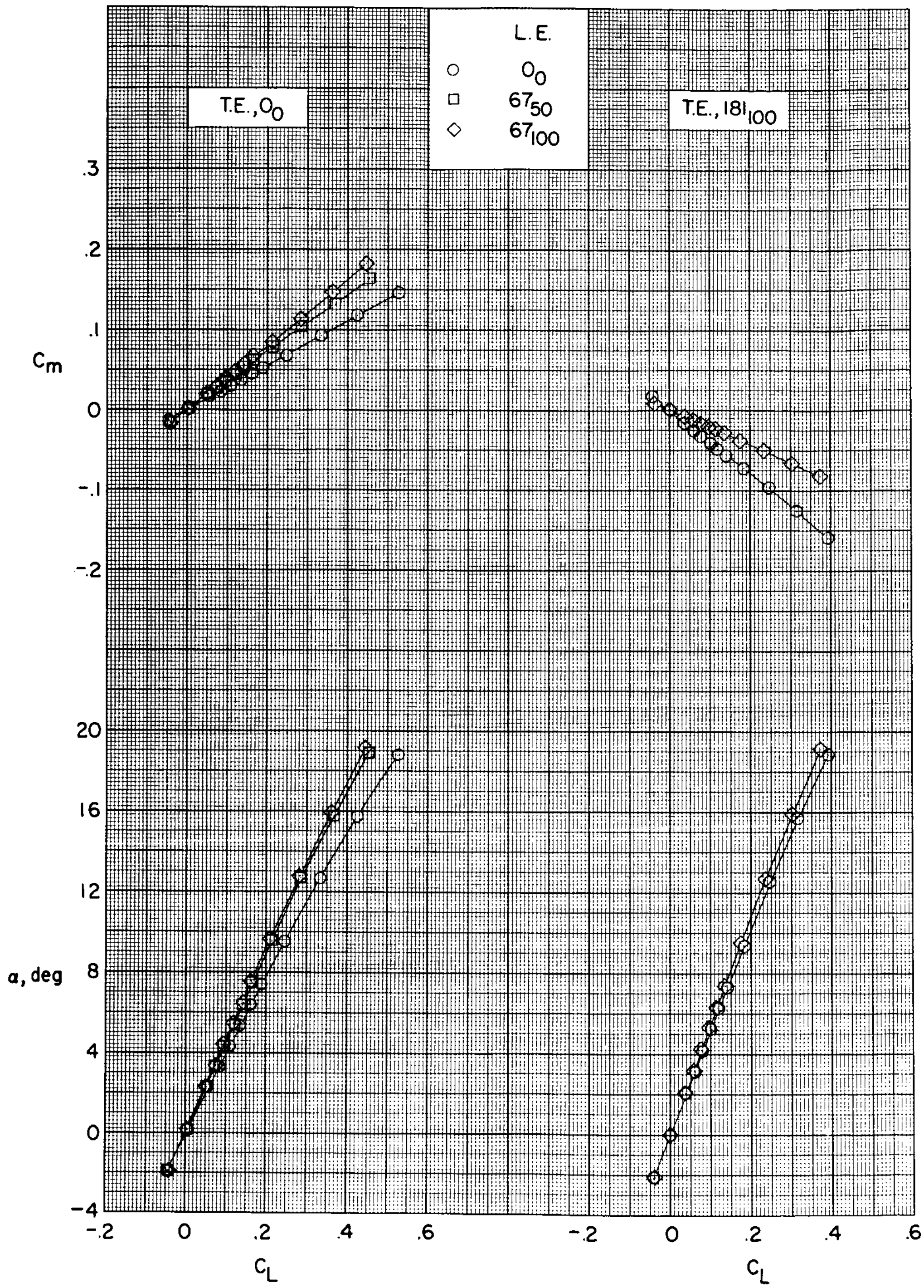


Figure 3.- Aerodynamic characteristics in pitch for body alone.



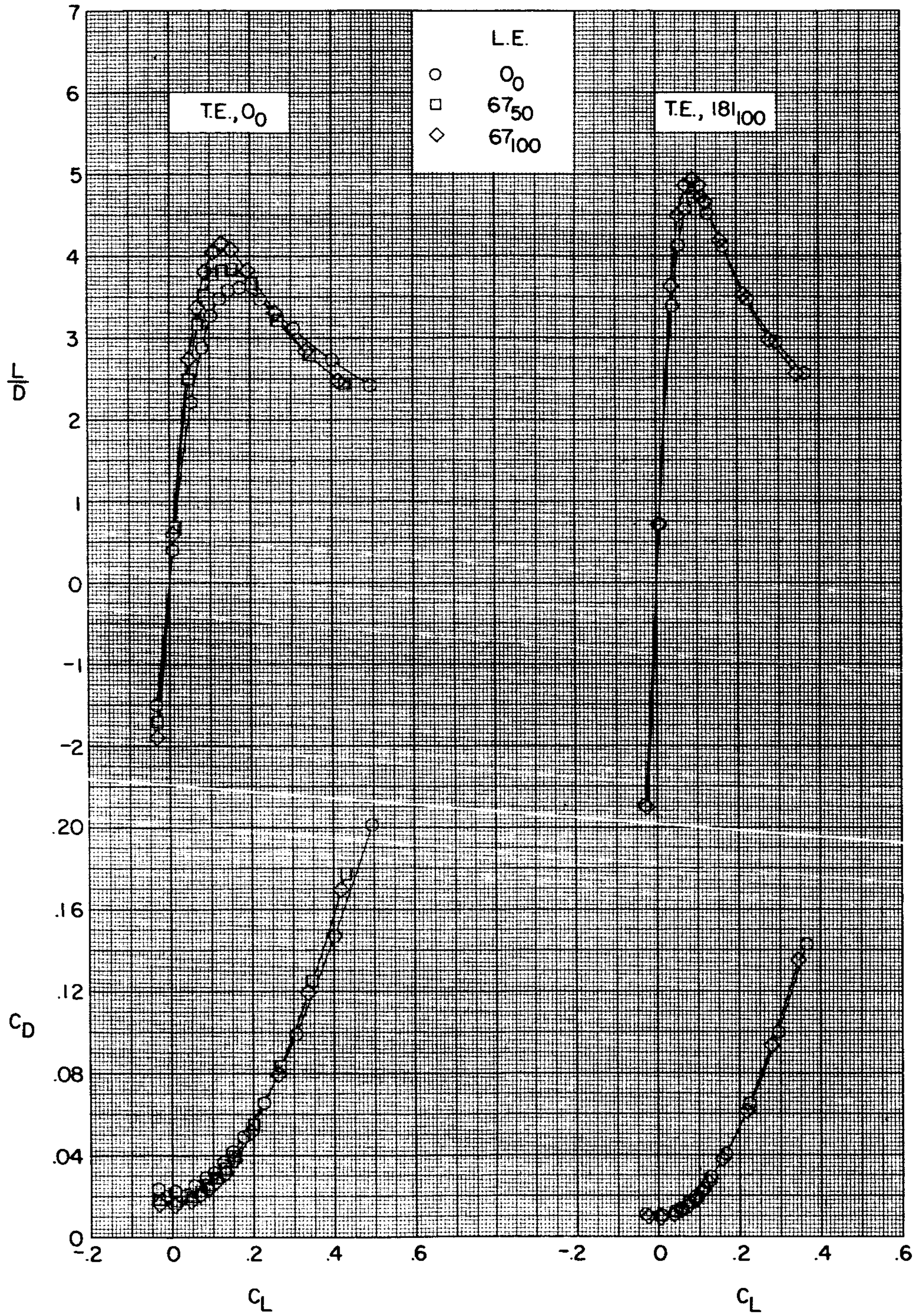
(a) M = 3.96.

Figure 4.- Aerodynamic characteristics in pitch for various test configurations with tail off. $\beta = 0^{\circ}$. (Data based on respective wing areas and model moment center.)



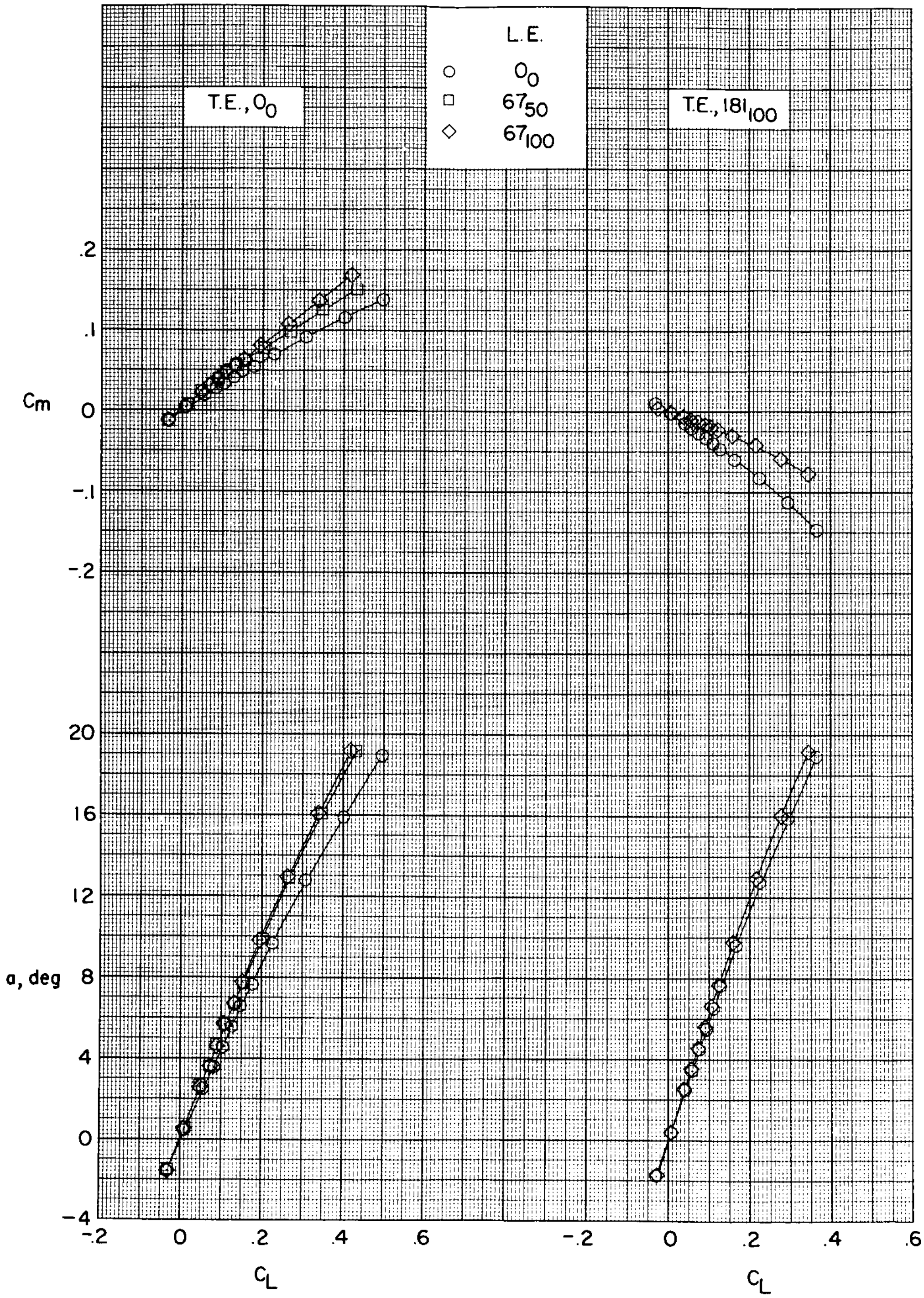
(a) M = 3.96. Concluded.

Figure 4.- Continued.



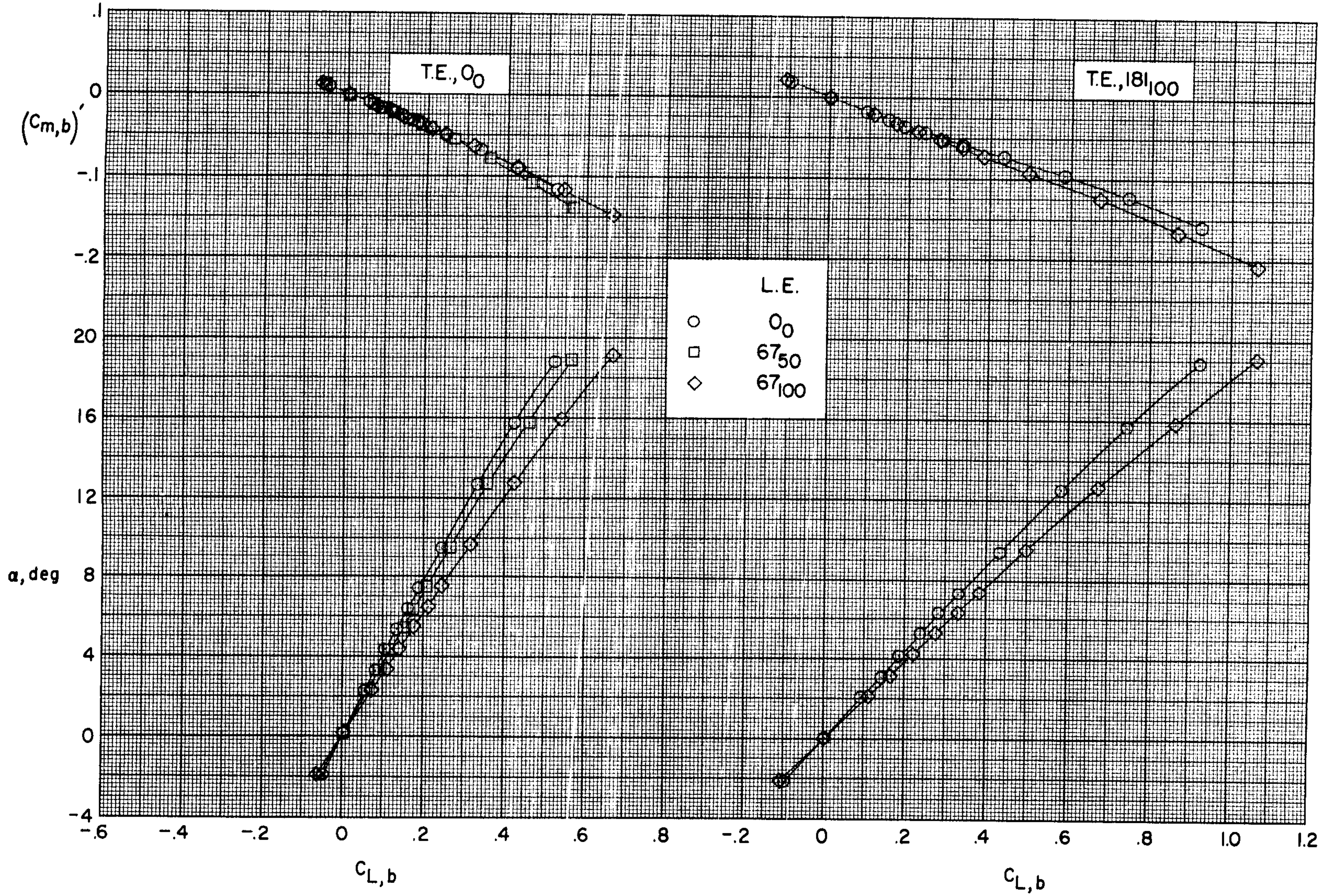
(b) M = 4.63.

Figure 4.- Continued.



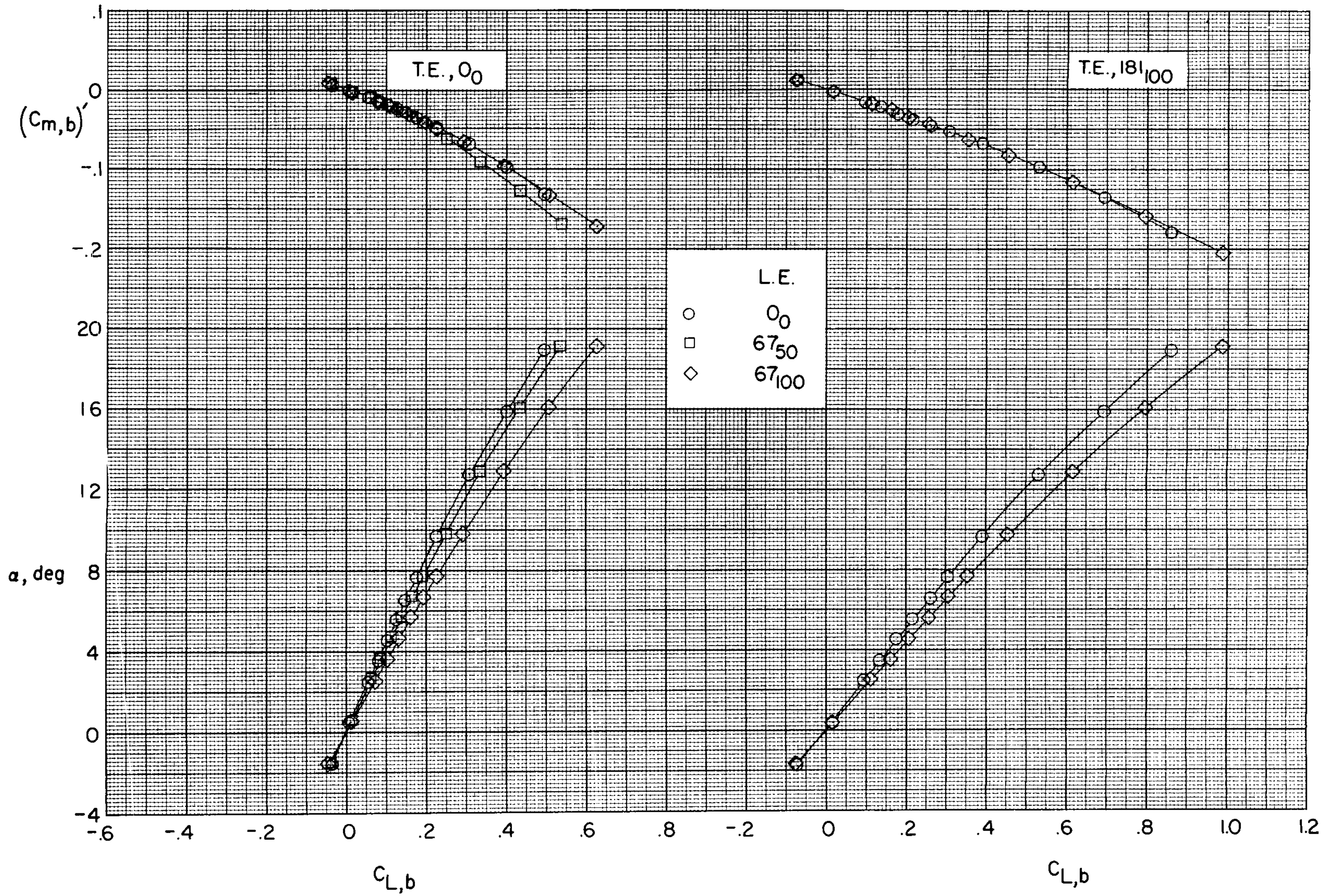
(b) M = 4.63. Concluded.

Figure 4.- Concluded.



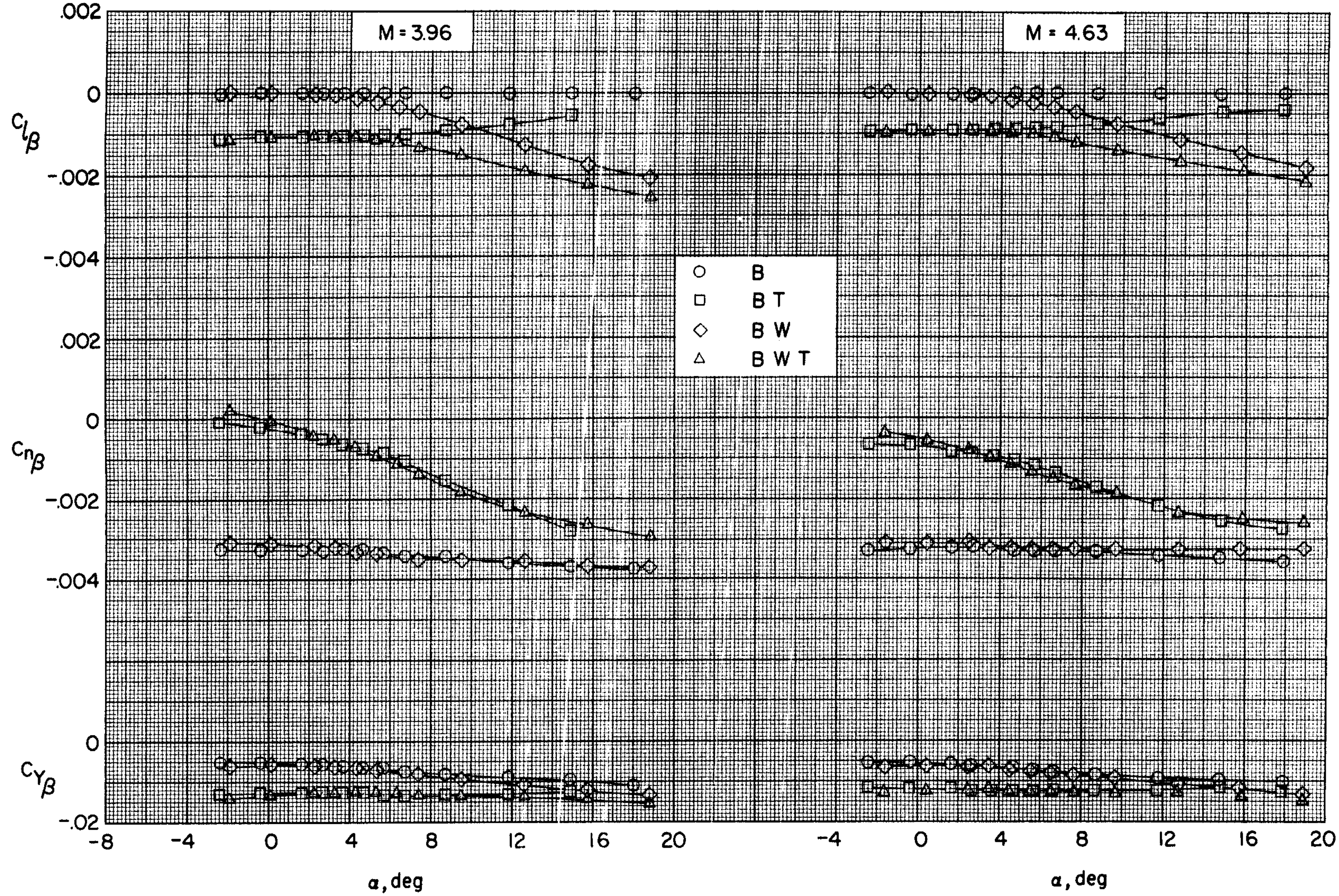
(a) M = 3.96.

Figure 5.- Aerodynamic characteristics in pitch for various test configurations with tail off. $\beta = 0^0$.
(Data based on area of basic wing and static margin of $0.185\bar{c}_b$.)



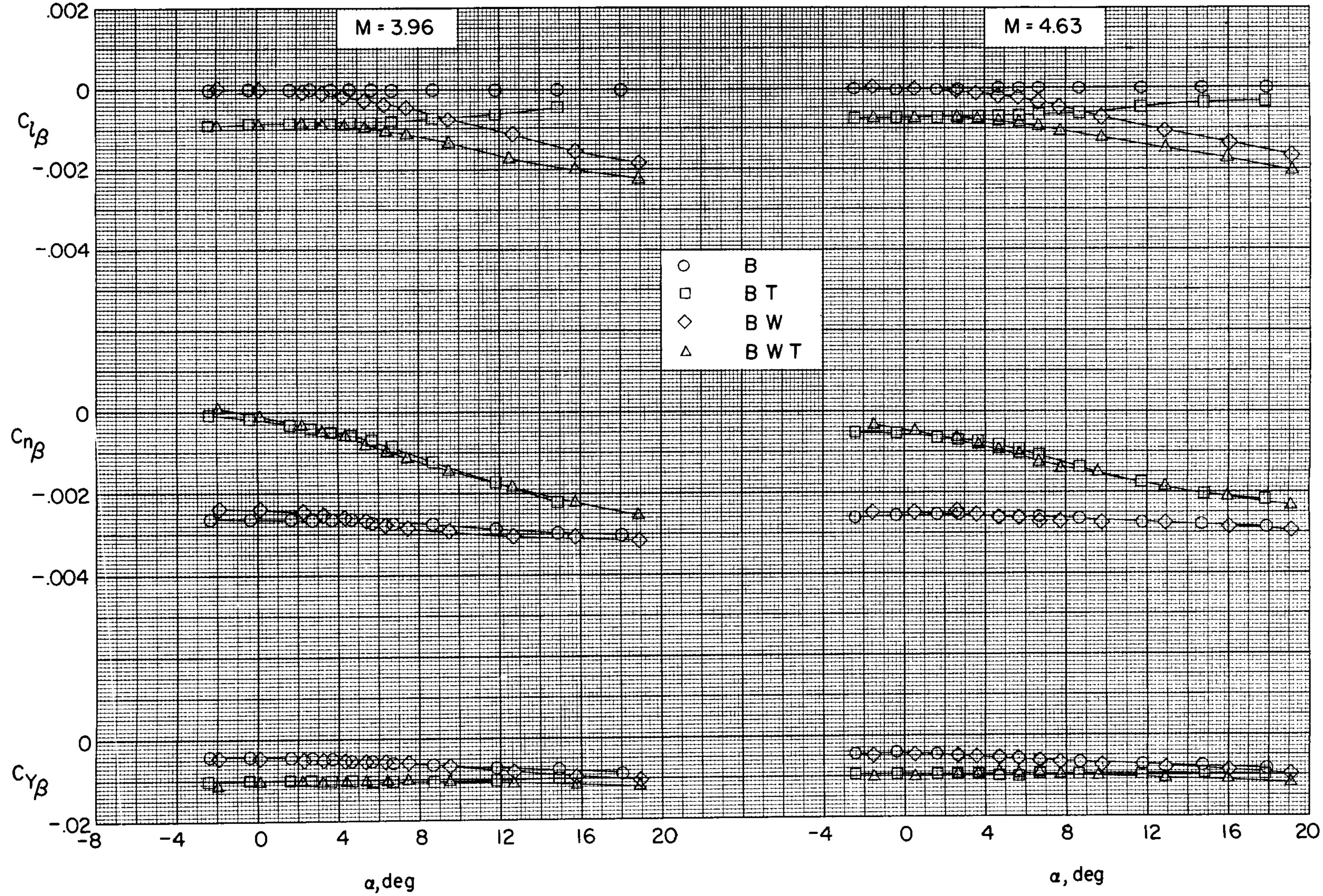
(b) M = 4.63.

Figure 5.- Concluded.



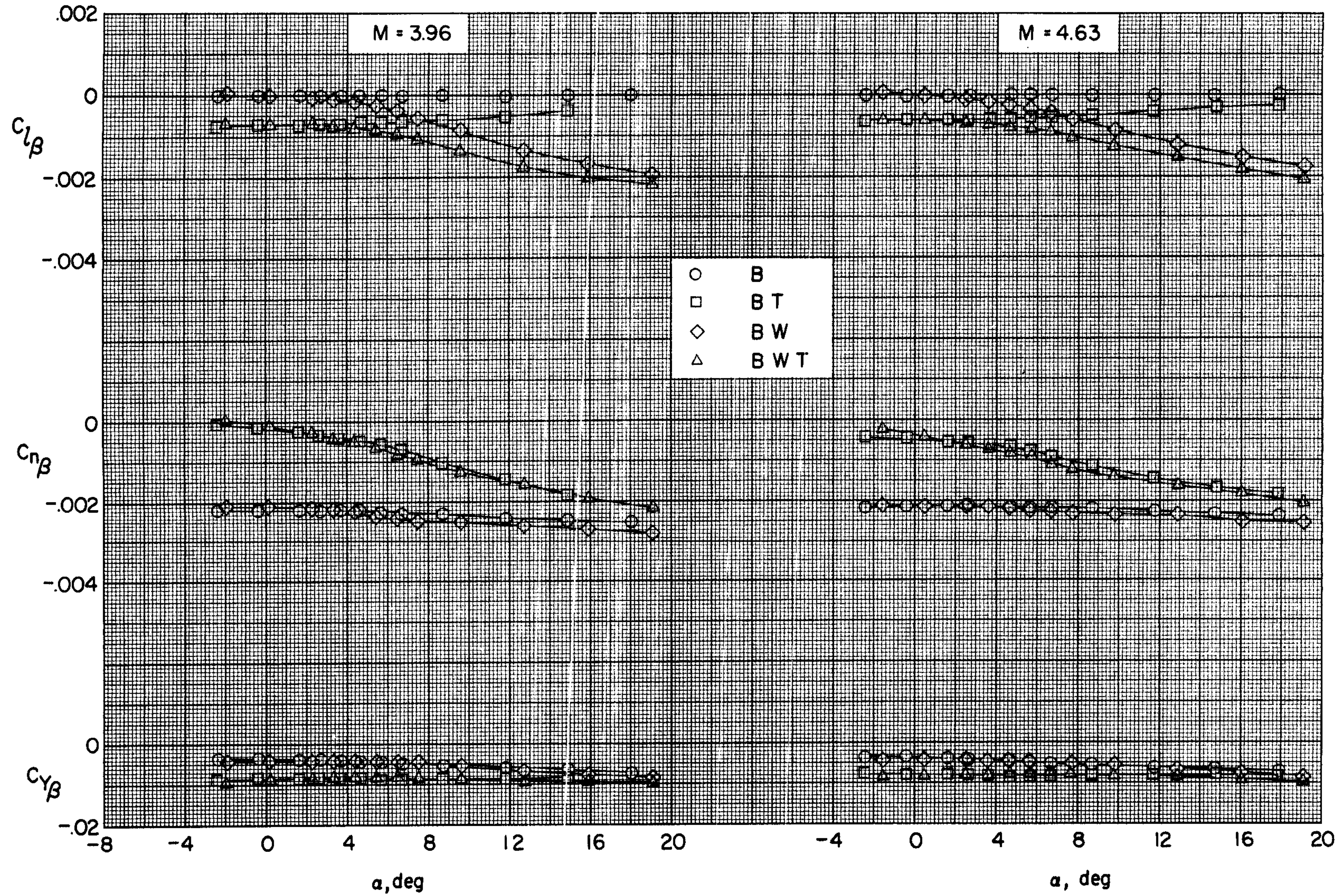
(a) 0_0-0_0 wing.

Figure 6.- Variation of sideslip parameters with angle of attack for various test configurations. (Data based on respective wing areas and model moment center.)



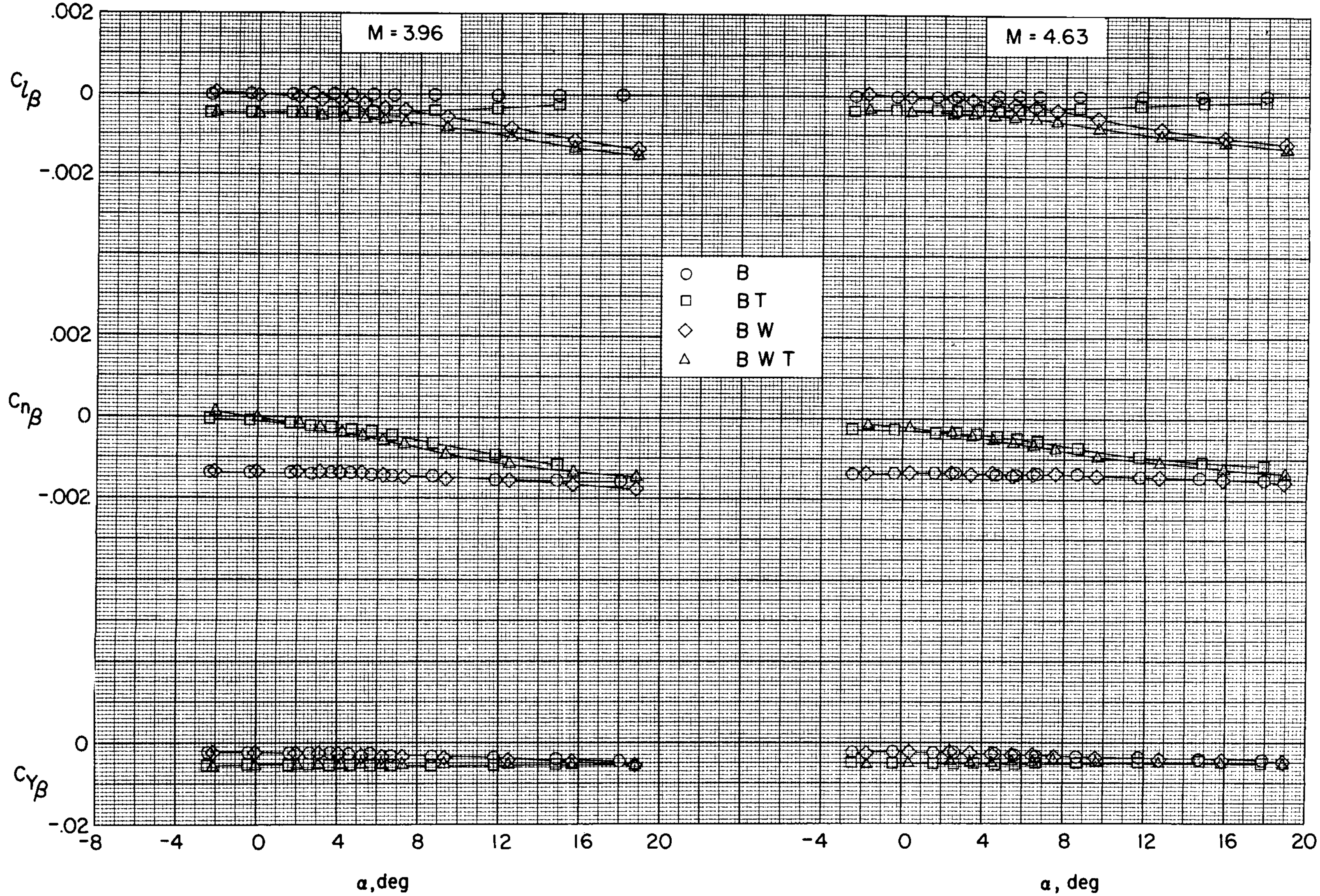
(b) 67_{50}-0_0 wing.

Figure 6.- Continued.



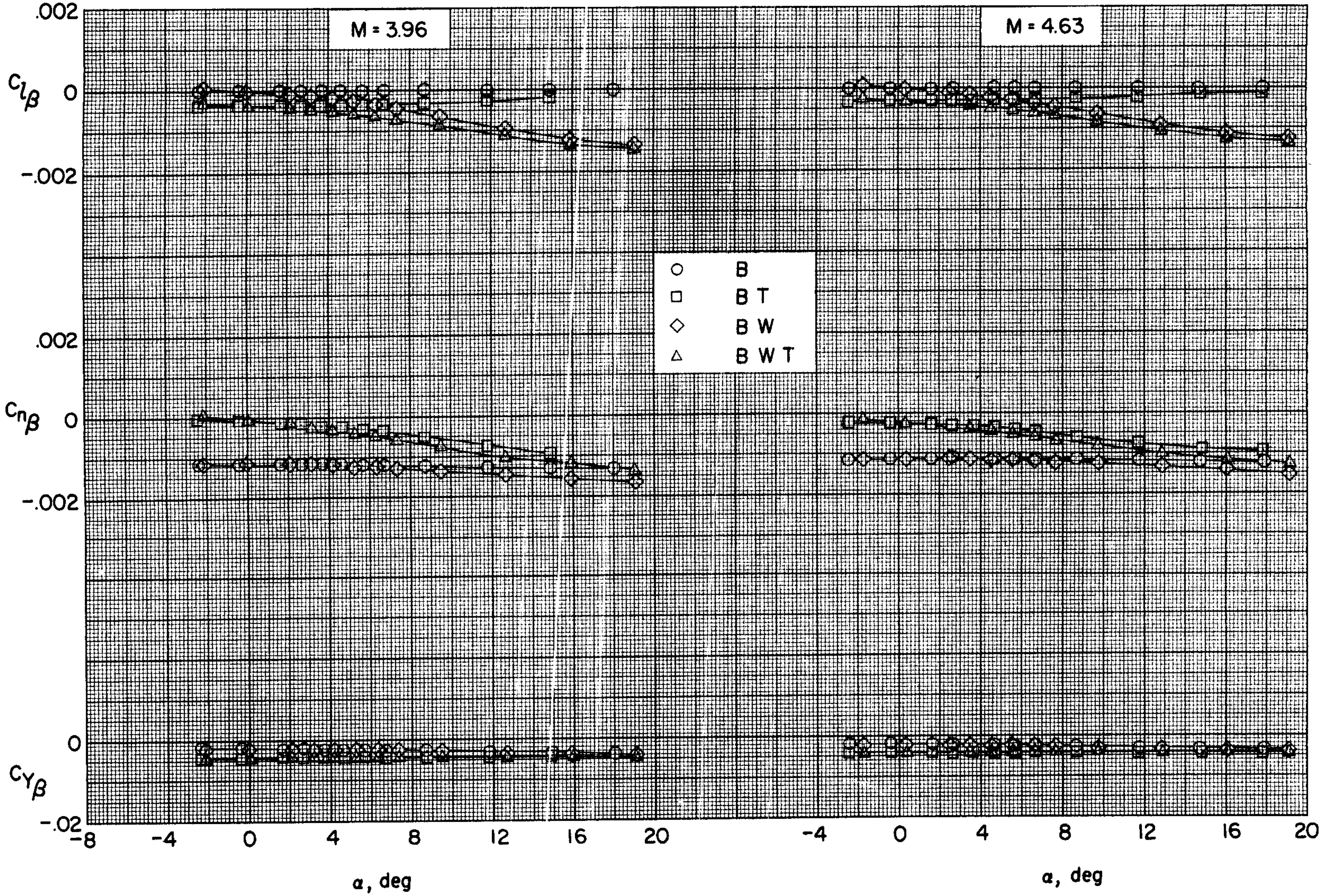
(c) 67_{100}-0_0 wing.

Figure 6.- Continued.



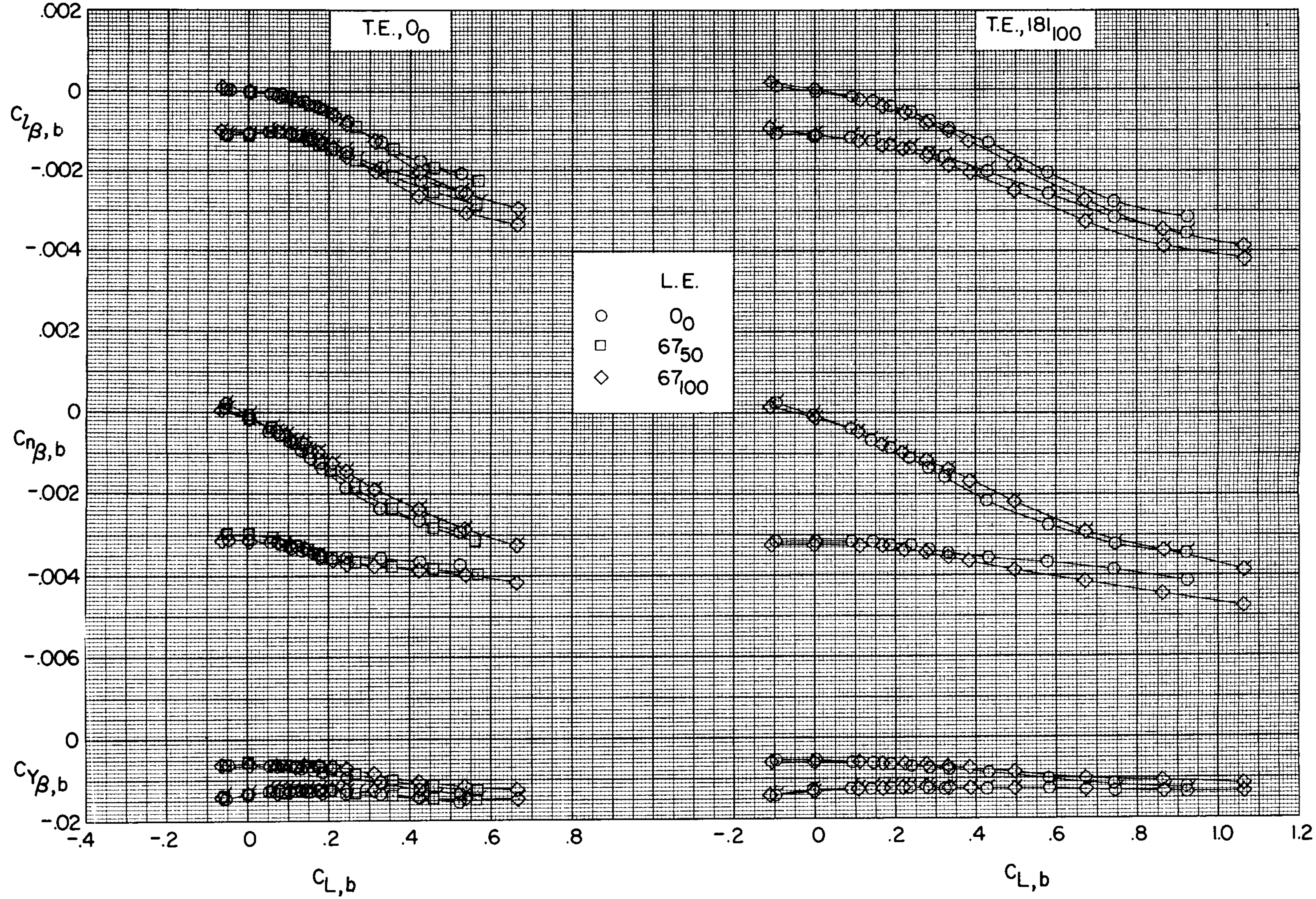
(d) 0_0-181_{100} wing.

Figure 6.- Continued.



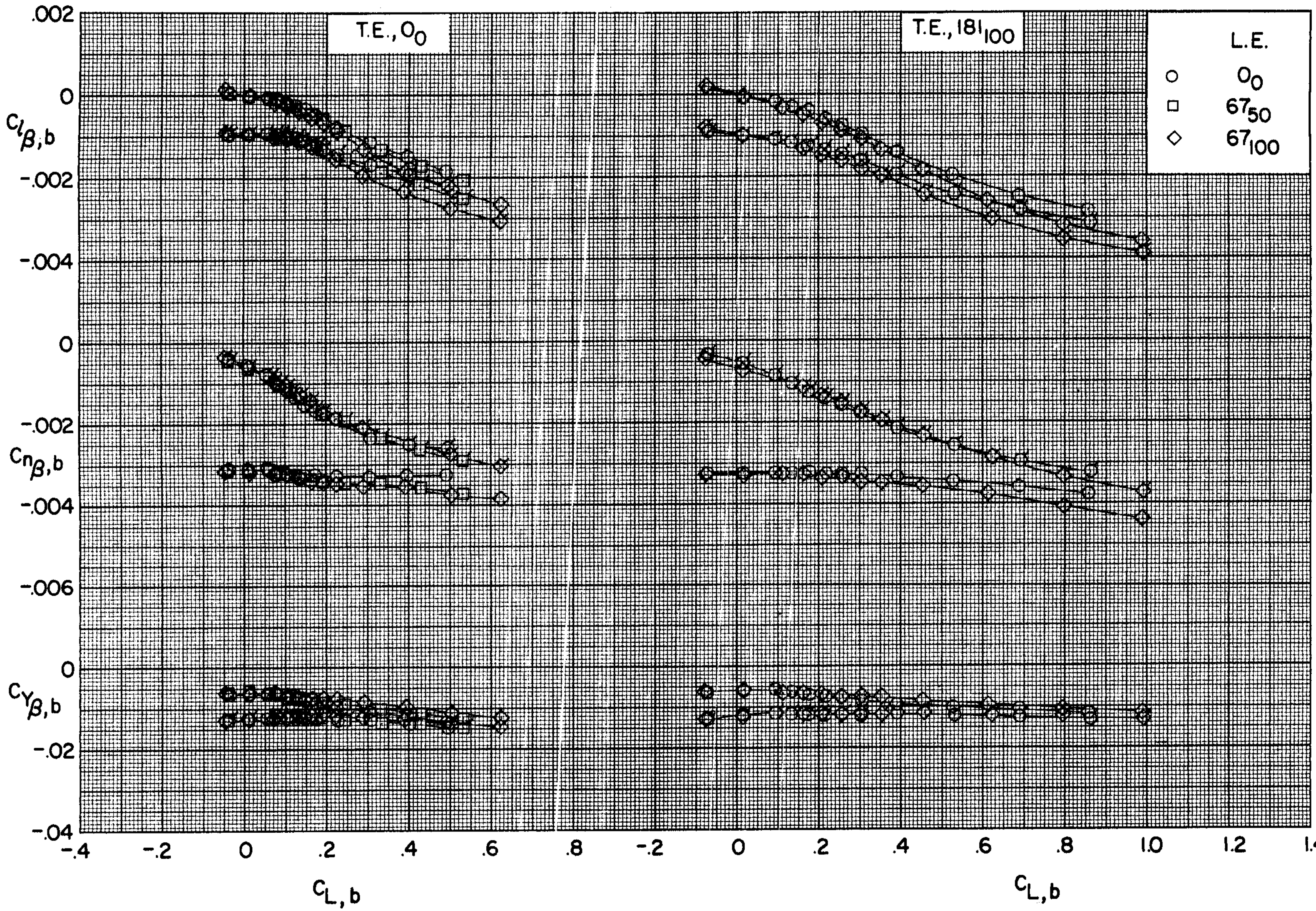
(e) 67_{100}-181_{100} wing.

Figure 6.- Concluded.



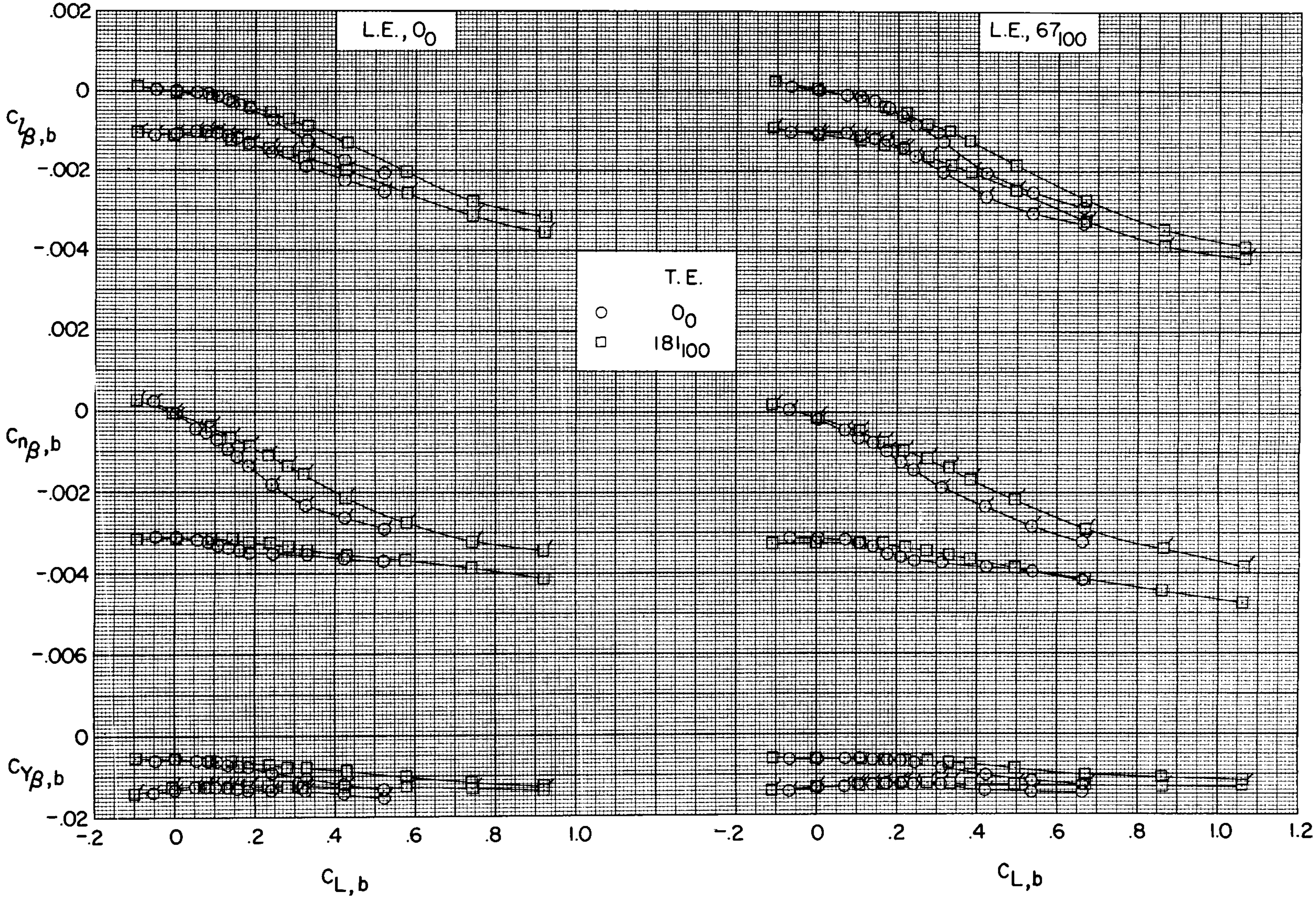
(a) M = 3.96.

Figure 7.- Effect of leading-edge extension on variation of sideslip parameters with lift coefficient. (Data based on area of basic wing and model moment center.) Flagged symbols indicate tail on.



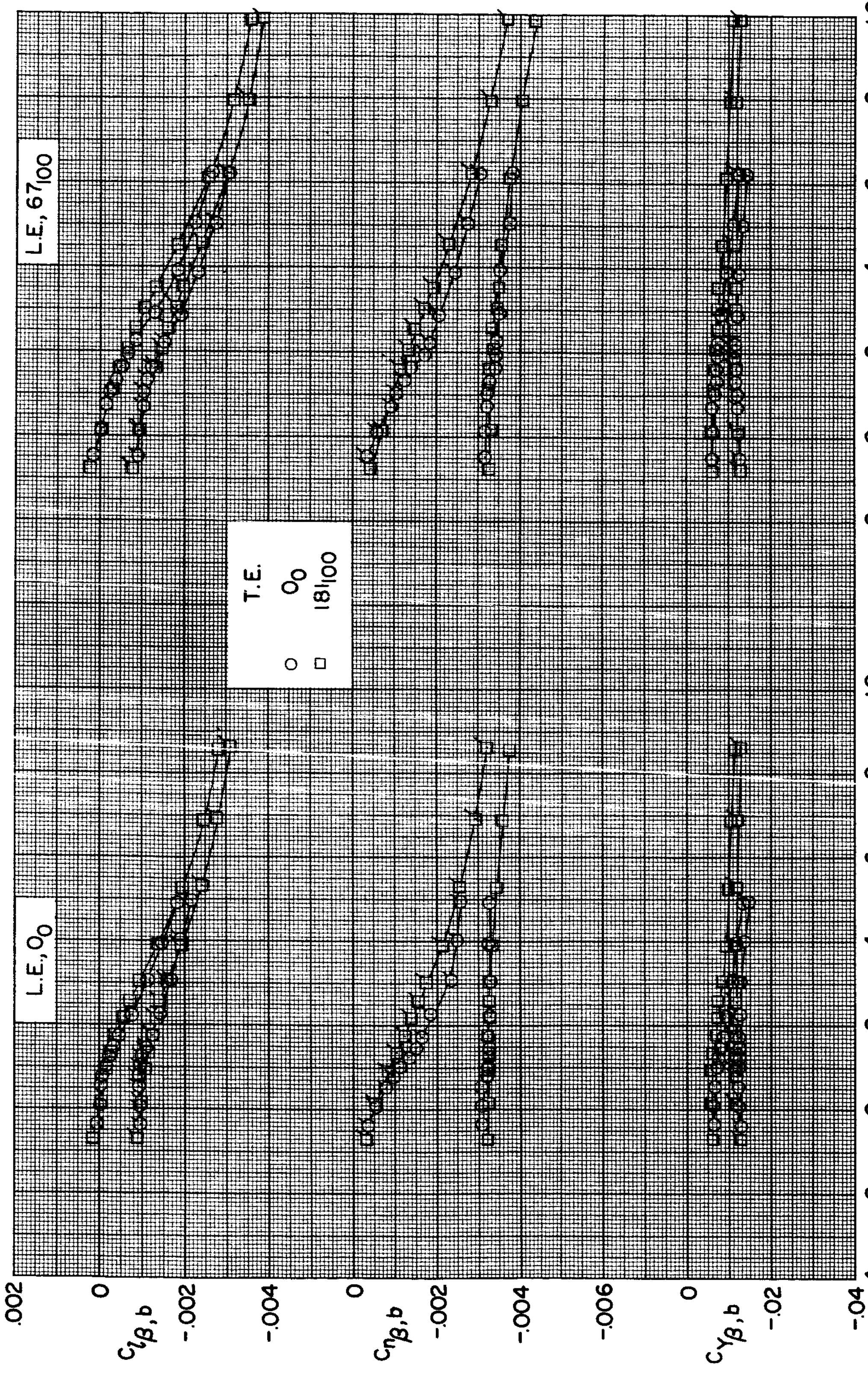
(b) M = 4.63.

Figure 7.- Concluded.



(a) M = 3.96.

Figure 8.- Effect of trailing-edge extension on variation of sideslip parameters with lift coefficient. (Data based on area of basic wing and model moment center.) Flagged symbols indicate tail on.



(b) M = 4.63.

Figure 8.- Concluded.

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